

WHAT IS CLAIMED IS:

See
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1. An electronically tunable dielectric material comprising at least one electronically tunable dielectric phase and a total of from about 1 to about 80 weight percent of at least two additional metal oxide phases.

2. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise a total of from about 3 to about 65 weight percent of the material.

3. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise a total of from about 5 to about 60 weight percent of the material.

4. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise a total of from about 10 to about 50 weight percent of the material.

5. The electronically tunable dielectric material of Claim 1, wherein the dielectric material consists essentially of two of the additional metal oxide phases.

6. The electronically tunable dielectric material of Claim 5, wherein the two additional metal oxide phases have a weight ratio of from about 1:100 to about 100:1.

7. The electronically tunable dielectric material of Claim 5, wherein the two additional metal oxide phases have a weight ratio of from about 1:10 to about 10:1.

8. The electronically tunable dielectric material of Claim 5, wherein the two additional metal oxide phases have a weight ratio of from about 1:5 to about 5:1.

9. The electronically tunable dielectric material of Claim 1, wherein the at least one electronically tunable dielectric phase is selected from barium strontium titanate, barium titanate, strontium titanate, barium calcium titanate, barium calcium zirconium titanate, lead titanate, lead zirconium titanate, lead lanthanum zirconium titanate, lead niobate, lead tantalate, potassium strontium niobate, sodium barium niobate/potassium phosphate, potassium niobate, lithium niobate, lithium tantalate, lanthanum tantalate, barium calcium zirconium titanate, sodium nitrate, and combinations thereof.

10. The electronically tunable dielectric material of Claim 1, wherein the at least one electronically tunable dielectric phase comprises barium strontium titanate.

11. The electronically tunable dielectric material of Claim 10, wherein the barium strontium titanate is of the formula $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$, where x is from about 0.15 to about 0.6.

12. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise oxides of at least two metals selected from Be, Mg, Ca, Sr, Ba, Ra, Li, Na, K, Rb, Cs, Al, Zr, Zn, Fr, B, Fe, Mn, Cu, Cr, Ti, Ta, Nb, Mo, W, Ni, Pd, Pb, Bi, Si, Sn, Hf and rare earths.

13. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise oxides of at least two metals selected from Mg, Si, Ca, Zr, Ti and Al.

14. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise at least two Mg-containing compounds.

15. The electronically tunable dielectric material of Claim 14, further comprising at least one Mg-free compound.

16. The electronically tunable dielectric material of Claim 15, wherein the Mg-free compound comprises an oxide of a metal selected from Si, Ca, Zr, Ti and Al.

17. The electronically tunable dielectric material of Claim 15, wherein the Mg-free compound comprises a rare earth oxide.

18. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise a Mg-containing compound and a Mg-free compound.

19. The electronically tunable dielectric material of Claim 18, wherein the Mg-free compound comprises an oxide of a metal selected from Ca, Si, Zr, Ti and Al.

20. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise at least one material selected from Mg_2SiO_4 , MgO , CaTiO_3 , MgZrSrTiO_6 , MgTiO_3 , MgAl_2O_4 , WO_3 , SnTiO_4 , ZrTiO_4 , CaSiO_3 , CaSnO_3 , CaWO_4 , CaZrO_3 , MgTa_2O_6 , MgZrO_3 , MnO_2 , PbO , Bi_2O_3 and La_2O_3 .

21. The electronically tunable dielectric material of Claim 1, wherein the additional metal oxide phases comprise at least one material selected from Mg_2SiO_4 , MgO , CaTiO_3 , MgZrSrTiO_6 , MgTiO_3 , MgAl_2O_4 , MgTa_2O_6 and MgZrO_3 .

22. The electronically tunable dielectric material of Claim 1, wherein the material has a tunability of at least 25 percent at 8V/micron.

23. The electronically tunable dielectric material of Claim 1, wherein the material has a tunability of at least 30 percent at 8V/micron.

24. A method of making an electronically tunable dielectric material comprising:

264 ? mixing particles of at least one electronically tunable dielectric material and a total of from about 1 to about 80 weight percent of particles of at least two additional metal oxide materials; and

sintering the material.

25. The method of Claim 24, wherein the electronically tunable dielectric particles and the additional metal oxide particles have average particle sizes of from about 0.1 to about 5 micron.

26. The method of Claim 24, wherein the electronically tunable dielectric particles and the additional metal oxide particles have average particle sizes of from about 1.5 to about 2.5 micron.

27. The method of Claim 24, wherein the additional metal oxide phases comprise a total of from about 3 to about 65 weight percent of the material.

28. The method of Claim 24, wherein the additional metal oxide phases comprise a total of from about 5 to about 60 weight percent of the material.

29. The method of Claim 24, wherein the additional metal oxide phases comprise a total of from about 10 to about 50 weight percent of the material.

30. The method of Claim 24, wherein the dielectric material consists essentially of two of the additional metal oxide phases.
31. The method of Claim 30, wherein the two additional metal oxide phases have a weight ratio of from about 1:100 to about 100:1.
32. The method of Claim 30, wherein the two additional metal oxide phases have a weight ratio of from about 1:10 to about 10:1.
33. The method of Claim 30, wherein the two additional metal oxide phases have a weight ratio of from about 1:5 to about 5:1.
34. The method of Claim 24, wherein the at least one electronically tunable dielectric phase is selected from barium strontium titanate, barium titanate, strontium titanate, barium calcium titanate, barium calcium zirconium titanate, lead titanate, lead zirconium titanate, lead lanthanum zirconium titanate, lead niobate, lead tantalate, potassium strontium niobate, sodium barium niobate/potassium phosphate, potassium niobate, lithium niobate, lithium tantalate, lanthanum tantalate, barium calcium zirconium titanate, sodium nitrate, and combinations thereof.
35. The method of Claim 24, wherein the at least one electronically tunable dielectric phase comprises barium strontium titanate.
36. The method of Claim 35, wherein the barium strontium titanate is of the formula $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$, where x is from about 0.15 to about 0.6.
37. The method of Claim 24, wherein the additional metal oxide phases comprise oxides of at least two metals selected from Be, Mg, Ca, Sr, Ba, Ra, Li, Na, K, Rb, Cs, Al, Zr, Zn, Fr, B, Fe, Mn, Cu, Cr, Ti, Ta, Nb, Mo, W, Ni, Pd, Pb, Bi, Si, Sn, Hf and rare earths.
38. The method of Claim 24, wherein the additional metal oxide phases comprise oxides of at least two metals selected from Mg, Si, Ca, Zr, Ti and Al.
39. The method of Claim 24, wherein the additional metal oxide phases comprise at least two Mg-containing compounds.
40. The method of Claim 39, further comprising at least one Mg-free compound.
41. The method of Claim 40, wherein the Mg-free compound comprises an oxide of a metal selected from Si, Ca, Zr, Ti and Al.

42. The method of Claim 40, wherein the Mg-free compound comprises a rare earth oxide.

43. The method of Claim 24, wherein the additional metal oxide phases comprise a Mg-containing compound and a Mg-free compound.

44. The method of Claim 43, wherein the Mg-free compound comprises an oxide of a metal selected from Si, Ca, Zr, Ti and Al.

45. The method of Claim 24, wherein the additional metal oxide phases comprise at least one material selected from Mg_2SiO_4 , MgO , CaTiO_3 , MgZrSrTiO_6 , MgTiO_3 , MgAl_2O_4 , WO_3 , SnTiO_4 , ZrTiO_4 , CaSiO_3 , CaSnO_3 , CaWO_4 , CaZrO_3 , MgTa_2O_6 , MgZrO_3 , MnO_2 , PbO , Bi_2O_3 and La_2O_3 .

46. The method of Claim 24, wherein the additional metal oxide phases comprise at least one material selected Mg_2SiO_4 , MgO , CaTiO_3 , MgZrSrTiO_6 , MgTiO_3 , MgAl_2O_4 , MgTa_2O_6 and MgZrO_3 .

47. The method of Claim 24, wherein the material has a tunability of at least 25 percent at 8V/micron.

48. The method of Claim 24, wherein the material has a tunability of at least 30 percent at 8V/micron.